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BACKFILLING PROBLEM IN THE ANTHRACITE REGION AS IT RELATES TO CONSERVATION OF ANTHRACITE AND PREVENTION ON SUBSIDENCE

BY

S. H. ASH AND JAMES WESTFIELD

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BACKFILLING PROBLEM IN THE ANTHRACITE REGION AS IT RELATES TO CONSERVATION OF ANTHRACITE AND PREVENTION OF SUBSIDENCE[1]

By S. H. Ash[2] and James Westfield[3]

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INTRODUCTION

The paramount responsibility of Government is to protect the general welfare. One of the chief functions of the Bureau of Mines is to investigate and publicize methods of increasing safety and efficiency in mining operations.

In an industrial civilization, energy resources constitute the foundation of a sound economic structure (14).[4] Coal is only one source of energy, but it provides more than half the energy consumed in the United States.

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Our coal reserves have been estimated at 3,000 billion net tons; more than half this total represents low-grade bituminous coal and lignite, and 15 billion tons, or less than one-half of 1 percent of the total, represents anthracite (14).

The anthracite industry produced 64,112,589 net tons of coal during 1944, of which 42,659,489 tons came from underground mines. Of the 78,145 employees, 51,887 worked underground (37). The records of the Pennsylvania Department of Mines from 1820 to 1944 indicate that more than 5 billion net tons of anthracite were produced at the mines in the region. Because much of the reserve underlies congested residential and business districts, it has been estimated that, if markets are available, 5 billion of the available 15 billion tons may be recovered under present mining conditions, which require that large pillars be left to minimize subsidence.

As the deposits of anthracite are confined almost entirely to Pennsylvania the difficulties of the anthracite industry have commonly been considered a State rather than a national problem (14). In the light of events during the past decade, this view may prove to have been short-sighted, and unless a program of remedial action to solve problems confronting the anthracite industry is undertaken soon, the expectation of many years' production still to be mined from anthracite reserves will not be attained (19).

Purpose of Report

Owing, at least in part, to intensive mining in the anthracite region during the present war, subsidence has occurred, as a result of which surface property has been damaged severely, lives have been lost or endangered, and underground workings have been seriously affected. Consequently, impetus has been given to the belief, strongly supported by public opinion, that an intensive program of filling the underground workings with waste materials would prevent such occurrences.

This report discusses, generally, several of the circumstances and factors that bear on such a program as it relates to conserving anthracite mines and anthracite, minimizing surface property damage, and preventing loss of life. It also discusses the possibility that the Federal Government should assume some financial responsibility in solving a problem that has long confronted not only the anthracite industry but the people who depend on that industry for their livelihood and as their main source of fuel for heat and power in many of the States east of the Mississippi River.

This report does not attempt to fix responsibility for property damage or loss of life or to advocate expenditure of extravagant sums of money by the industry or governmental agencies.

Conservation Measures

Mining is conducted for profit in the United States, and unless a profit can be realized, a mining enterprise cannot long exist. The belief has gained strength in recent years that our mineral resources can be conserved

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as well as mined profitably; consequently, there has been some legislation, State and Federal, in the interest of conservation (26). With respect to the anthracite industry, governmental activities in the matter of conservation have not been instituted largely because the industry has not advocated such a policy. This is reflected by the fact that essentially nothing (other than war measures) in the nature of governmental control has been done with respect to conservation.

In the anthracite region, conservational practices have been conducted in individual instances and are being utilized by the industry itself (4, 15, 21, 29, 32, 33, 40) chiefly in the interest of greater efficiency of operation, though influenced to some extent by laws, wage controls, public sentiment, and problems bearing on flooding (2, 13, 19, 37), culm disposal (11,18, 30, 33, 38), and mining subsidence (20, 28, 35).

The value of a mineral is affected in numerous ways by conservation measures. A popular concept of the value of a ton of coal is that it is equivalent to every other ton of similar grade regardless of its origin. In reality, the value of a ton of coal, like the value of any other mineral, is largely man-made and depends on the consumer's capacity to make use of the coal, with particular reference to its utility as compared with that of other competitive sources of energy; it shifts with the consumer's needs and preferences and, most important, the price of coal to the consumer.

The Bureau of Mines has long advocated and suggested more widespread use of mining practices that were instituted by the anthracite industry itself to conserve anthracite (4, 7, 15, 20). Joseph A. Holmes, the first Director of the Bureau of Mines, in 1912 stated: "The perpetuation of the supply of anthracite coal in Pennsylvania is a national as well as a State problem. Any investigation that shows how larger percentages of this coal may be saved in mining, without excessive cost and without dangerous subsidence of the overlying surface ground, has a national as well as a local interest" (20).

Study of anthracite mining shows that for the industry as a whole and in long-range perspective the effects of conservation measures are beneficial, in that they tend towards stabilization of production and prices, a larger percentage recovery of coal with a proportionally longer life of any individual mine as well as of the entire industry, greater safety, and a surer margin of profit. Conservational measures are not in general effect chiefly because individual mines may be affected adversely at times to the extent to which such measures rule out quick profits and appear to require ruthless exploitation at the expense of the industry as a whole.

The need for solving serious problems resulting from anthracite mining is recognized (19, 20, 28, 38); most of these problems are interrelated and bear on conservation of anthracite and prevention of human distress, but now it is beyond the financial ability of the industry to deal with them effectively (2, 13, 16, 19, 37).

In 1938 the Pennsylvania Anthracite Coal Commission recommended that the State purchase excess anthracite reserves in Pennsylvania, to be worked

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later by private companies under a leasing arrangement (6). Because of the compactness of the area (480 square miles), single ownership could do much to conserve the coal resources by (a) promoting unified development of mining, (b) standardizing mining practices, (c) conducting action programs to prevent flooding, mine fires, and subsidence, (d) preventing cut-throat competition, and (e) conducting research work on utilization of anthracite.

As the mining of anthracite by private enterprise is favored, and much of the damage affecting anthracite reserves has already been done, remedial measures should be taken to avoid further losses. In the event of failure of the Commonwealth of Pennsylvania to act, the need for conservation of anthracite indicates that the Federal Government should assume responsibility (2, 14, 19, 37). Preferably, the problem is now one for cooperative effort on the part of the anthracite industry and the State and Federal governments.

Mining Methods

The earliest commercial mining operation in the anthracite region was the Summit Hill stripping operation in 1821. Stripping was employed because no other method seemed feasible to the early operators (40).

Although stripping has been continuous since 1821 (21, 32), to obtain a larger tonnage at a lower development cost a large stripping program has been put into effect during the past decade.

In 1932, 7 percent of the total anthracite output was obtained by stripping. During the next 10 years this percentage increased, until now it is 15 percent. Several stripping operations produce 50,000 tons a month, and it is in this direction that mechanical mining has made rapid strides (21, 32).

The basic method of underground mining is virtually unchanged, but modifications have been necessary to cope with changing bed conditions.

The general practice of underground mining has been the room- (or chamber- or breast-) and-pillar method. Although other systems are in use, such as the longwall (24), the conventional method named predominates (4, 13, 20, 24, 28, 29).

A considerable portion of the surface in the anthracite region has been disturbed by stripping and robbing (pillar-pulling) operations, although the policy of most companies until recent years has been to confine such operations to outlying and unimproved surface areas. Virgin coal that can be mined by underground methods is now largely restricted by beds underlying improved surface areas. A real problem must be solved to permit robbing (pillar-pulling) operations or complete removal of pillars under improved surface areas if reserves are to be recovered.

In the early days of mining, only the thicker and better beds of coal were mined, largely because mining and coal-cleaning facilities were

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inadequate and the number of productive beds available was small; therefore, many of the thinner and less-productive beds were not mined. Many of these latter beds overlie the mined-out areas of the thicker and better beds. Some collieries are now relying on thinner and less-productive beds that remain in the areas where the thicker beds have been wholly or partly removed (4, 29).

Mining Subsidence

What was true of mining methods in early anthracite-mining history is generally true today, in that practice still is to mine only the best, thickest, and most accessible beds; also, it is customary to take only the profitable parts of each bed and to leave as refuse the parts that are more expensive to work.

Remining of beds in the anthracite region is as prevalent today as it was 35 years ago. As a result, "squeezes" are common, weakening of pillars is inevitable, and rapid subsidence occurs in unexpected places. Under such conditions there is no assurance that pillars (barrier or otherwise) can or will serve the purpose for which they were originally intended. As a result, millions of dollars are or should be expended in filling, reinforcing barrier or supporting pillars, and otherwise protecting mine workings and surface structures. One important question is: What can be done and who is going to pay for doing similar work in abandoned mines that should receive similar treatment?

Numerous and serious cavings or subsidences of the surface which have caused damage to surface property and loss in life in the anthracite industry, have made the general public realize the seriousness of subsidence. However, there are also other matters attributable to subsidence that are not noticed by the general public unless loss of life occurs - barrier pillars are crushed and may fail with catastrophic results when impounded water is released; pillars left for support are crushed by "squeezes," and mining is costly or impossible; strata intervening between mined-out areas and water-bearing strata or surface bodies of water are broken, allowing enormous amounts of water to enter mine workings. In operating mines, this water must be delivered to expensive pumping plants and must be pumped to the surface at great expense. In abandoned mines the water accumulates as a constant menace to adjacent mines.

The process of mining is followed inevitably by some degree of sinking of the overlying strata and consequently of the surface. The subject of mining subsidence is filled with uncertainties, contradictions, and difficulties of interpretation. It is true, regardless of the nature of an underground excavation and the method of roof support, that subsidence of the ground above the excavation is very likely to be the final incident in mining.

A sharp distinction has to be drawn between subsidence and damage resulting from subsidence (5, 28). Probably the bulk of coal has been extracted without causing any damage. Nevertheless, the cost of subsidence to the mining industry and to the general community is important; no one

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living in a thickly populated mining district such as the anthracite region, where many of the surface improvements have been made on ground overlying the best coal resources, has far to look for examples of damage caused by subsidence (17).

Loss of life due to subsidence in a thickly populated area attracts the public's attention to the danger of subsidence and inevitably arouses it to demand remedial action.

Injury to public property such as schools, municipal buildings, hospitals, sidewalks, streets, gas and water mains, and the like attracts more attention than damage to dwelling houses. Serious consequences often follow damage to utility services, particularly when gas, water, and electricity mains are damaged. Damage to bridges, railroads, tunnels, highways, sewers and sewage systems also causes a community to realize the danger of subsidence.

Mine workings in which pillars have been left to support the roof under populated centers often have been abandoned for some reason and allowed to fill with water. Subsidence may occur after unwatering flooded mines, owing to the removal of hydrostatic support.

In the past, as now, the anthracite region has been concerned with experiences such as those mentioned above. Furthermore, the industry is confronted with a flood-preventing problem (2, 15, 19, 37) that involves combating not surface waters alone but also billions of gallons of water impounded in underground pools in abandoned workings, and in the strata. The question of subsidence assumes, for underwater workings, an importance transcending that of perhaps any other circumstance involving subsidence.

The risk of inundation in sections of underground workings in the anthracite region is increased by the presence in the strata overlying active mine workings of channels filled with loosely consolidated water-bearing material - as in the Wyoming region of the Northern Field (7, 19) - or of faults that, if not providing easy ingress to water, may provide such when subsidence has occurred (8). Sudden subsidence may cause the inundation of mines (1) and in some cases take a heavy toll of underground workers.

The cost of pumping alone is a serious problem in subsidence in the anthracite region. Not only are millions of dollars spent annually to protect the mines from the inflow of surface water, but millions of tons of coal are lost irrevocably in protective pillars and in areas reserved under rivers, creeks, swamps, and "buried valleys" in order to protect lives and property from sudden floods or inrushes of water due to floods or breaks in the surface caused by subsidence (19).

To deal at all adequately with the technical details of subsidence is beyond the scope of this report. Subsidence in mines has been a matter of interest since the Belgian committee for subsidence in the city of Liege submitted its first report in 1825. Landsberg (25) prepared a bibliography that, although incomplete, comprises more than 800 titles of articles on

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the subject. In spite of all the studies that have been made and the reports that have been written, the problem remains very acute today (5, 22, 25, 31, 35, 36, 42), especially as to individual locations.

Reports on subsidence that treat solely with anthracite problems have been made, and some have been published in the technical literature. These reports have followed incidents that resulted in damage of some sort to surface improvements. Griffith and Conner (20), Mentz and Norris (28), and Moore and Powell (29) have discussed subsidence in the anthracite region, and their reports are essentially as pertinent today as on the day they were written.

As a result of serious cave-ins of the surface in some of the cities and towns in the anthracite region, particularly in Scranton, from 1909 to 1911, which destroyed surface buildings, public and private, and seriously endangered life, and because city commissions and private agreements failed to restore confidence or to remedy conditions, a mine-cave commission was created by an act of the Legislature of Pennsylvania approved March 24, 1911 (35).

The Pennsylvania State Anthracite Mine-Cave Commission was created "for the purpose of investigating and reporting upon both physical conditions and legal rights in the matter of surface support, where anthracite coal has been removed, or the right to remove said coal is vested in others than the owner of the surface, and for the further purpose of suggesting new legislation relative to same***."

Reference is made in the commission's report to the valuable earlier report of Griffith and Connor (20), Mining Conditions Under the City of Scranton, which was published in 1912 as Bureau of Mines Bulletin 25, with a preface by J. A. Holmes and a brief chapter on sources of material in the region for mine filling by N. H. Darton (7) of the United States Geological Survey. The commission's report remains unpublished.

As a result of serious cave-ins in recent years, an Anthracite Subsidence Commission was appointed under Act 295, P. L. 802, 1942 "to make a study and investigation of the various problems related to the surface subsidence frequently caused by the mining of anthracite coal; directing such commission to make a report and recommendations to the General Assembly***." It is the duty of such commission:

1. To investigate the problem of surface subsidence in the anthracite coal area with respect to its effect on property and human life;

2. To engage in any research necessary to discover effective remedies for the anthracite mine-cave problem;

3. To study decisions of the State and Federal courts relating to the constitutionality and effect of earlier legislation relating to surface subsidence caused by mining; and

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4. To make recommendations as to legislation which might be enacted by the General Assembly for the effective regulation and control of anthracite mining and surface subsidence.

The commission shall make its report to the General Assembly not later than the first day of February, one thousand nine hundred and forty-three.

The report of the commission remains unpublished.

A study of surface subsidence was made by the Pennsylvania Department of Mines in 1943 and was submitted to the Mine Subsidence Committee of the General Assembly during the session of the Legislature.

Following a conference with the above commission on February 25, 1943, a committee of mining engineers representing operators in the anthracite industry was requested to submit and did submit, to the commission supplemental information regarding the cost of a proposal to flush mine openings under improved surface areas in the region and the probable effect of subsequent removal of pillar support in the flushed or hydraulically filled areas.

The important angles from which to regard the subsidence problem are (a) safety of mining operations, (b) maximum recovery of anthracite, and (c) protection of property (25).

SAFEGUARDING AGAINST SUBSIDENCE AND ITS EFFECTS

Subsidence caused by mining cannot be prevented; however, the damage caused by subsidence may be prevented, or at least lessened, either (a) by leaving beneath the property, river, stream, swamp, body of water, or other potentially dangerous factor an adequate pillar in the coal bed, or (b) by mining in such a way that subsidence or its harmful consequences, is minimized.

The harmful consequence of subsidence can be prevented or lessened by tightly filling the mine workings with refuse materials when the coal is extracted and the mine workings are open for inspection, and, in the case of surface improvements, by placing them or so constructing them that the chance of serious injury is obviated or reduced.

The word "backfilling" in this report will be used to mean filling the mine workings with materials of any description that give strata support and is synonymous with "stowing," "hydraulic stowing," "waste filling," "pneumatic stowage," and "hydraulic mine filling." The process of filling the mine workings with materials transported by water is known in the Pennsylvania anthracite region as "slushing," "flushing," "silting," "hydraulic backfilling," and "hydraulic mine filling." Enzian (15), in describing the hydraulic process of backfilling in the anthracite region, has used the term "hydraulic mine filling." "Hydraulic backfilling" has come into usage more recently. It describes the process simply and is used by the authors

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in this report and, unless otherwise stated, will mean the use of water and culm, or silt, for backfilling.

There are at least five methods of placing sand, culm, tailings, or other similarly sized filling materials in mines: By hand, by water, by compressed air, by a combination of compressed air and water, and by a centrifugal action of a mechanical device similar to a mining fan (9, 12).

Use of Pillars

The method of leaving pillars to protect surface improvements and mine workings or to protect against surface hazards will not be discussed in this report. Utilization of pillars, such as barrier pillars, to separate mines for ventilating purposes or to protect mines from being flooded by water impounded in contiguous mine workings or from mine fires that have gotten beyond control are matters governed by State laws. Insofar as subsidence is concerned, large barrier or protective pillars can, in some instances, by sustaining the strata overlying them, cause more damage to surface improvements than probably would be the case if they were not in existence; this is due to uneven subsidence of ground above contiguous mine workings (5, 20, 28, 29, 39) where these large pillars are left.

Roof Support

The problem of roof support as it relates to mining subsidence has been dealt with in detail in many publications (25). From the viewpoints of conservation of our mineral resources and the purpose of removing all mineral other than that unavoidably lost by mining, the problem of roof support presupposes some method that will support the roof in such manner as to permit maximum recovery of the mineral resource and at the same time minimize subsidence to a degree that human life is not jeopardized, the safety of the mine is maintained, and damage to surface improvements is nonexistent or negligible.

Well-informed mining men, based upon experience in the various branches of the mineral industry, are generally of the opinion that roof support for the purposes mentioned above can be attained only by some system of "backfilling" (5, 10, 11, 25, 27, 28, 36, 42).

Ashmead (4), Darton (7), Dierks (10), Enzian (15), Griffith (20), Norris (28), Rice (35), and others have discussed roof control in reports that treat solely of anthracite problems. Exhaustive tests have been made to determine the compressive strength of artificial supports of various kinds used in mining anthracite in Pennsylvania, as well as the compressive strength of anthracite specimens (35). It is not because data regarding roof support in anthracite mining are not known or available that subsidence is and has been an acute problem in this region, but rather because subsidence cannot be prevented by any artificial means where the anthracite already has been removed; however, subsidence usually can be minimized by controlled backfilling. Where a cave-in or severe damage is caused by subsidence, it is likely to be due to failure to backfill the workings or to

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inefficient or incomplete backfilling, or possibly to the fact that backfilling was too long delayed.

Hydraulic Backfilling

Hydraulic backfilling is thought to have been done first in the anthracite region of Pennsylvania (5). It was originated by a Catholic priest in the city of Shenandoah in 1864, who, in the hope of saving his church from destruction by subsidence, prevailed upon the president of the Philadeophia and Reading Coal & Iron Co. to "slush" the breaker waste and culm into the old mine workings beneath his church. The project was a success. The hydraulic backfilling methods now in use started thus and, aside from mechanical methods of preparing the backfilling materials and transporting them into the underground workings, are about the same today (4):

From 1884 to 1887, inclusive, hydraulic backfilling was introduced in the anthractie region for the purposes of (a) sealing off mine fires or extinguishing them, (b) arresting squeezes, and (c) supporting the surface (15). Engineers from Europe became interested and visited Pennsylvania, with the result that hydraulic backfilling has now become highly developed in Continental Europe and is also used in Australia and The Rand (5, 9, 27). Hydraulic backfilling has been used extensively in metal mines (12), particularly for controlling or extinguishing fires (12, 34) both in the United States and abroad.

One of the specific purposes of hydraulic backfilling of rooms (or chambers, or breasts) in the anthracite region at present is to furnish artificial support so that coal pillars can be recovered without caving of the roof strata (11).

Various materials have been used for packing - culm or silt, sand, crushed rock and washery refuse, ashes, tailings, and salt. Silt or culm is the material commonly used in the anthracite region; this is finely divided dirt from anthracite mines and may contain some coal.

Since 1887, hydraulic backfilling has been an important part of mining, particularly in the northern anthracite basin, where the gentle dip of the beds and shallowness of mine workings favor it. The application of hydraulic backfilling also has been favored by the fact that in the northern field a high percentage of mining is done under cities and boroughs, where protection is required for surface improvements.

There is hardly a mining company in the Wyoming Region that has not done hydraulic backfilling in the past, and many are so engaged now.

Prior to the beginning of World War I, hydraulic backfilling was practiced extensively (11); it was curtailed gradually during the war, however, owing chiefly to an acute shortage of labor. Backfilling declined steadily during the depression years, and in the 1930's economic conditions caused it to cease almost completely; consequently, more and more mines resorted to culm disposal which is less expensive than hydraulic backfilling, with

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the result that open, unsupported, underground workings increased considerably.

Hydraulic backfilling is expensive and few companies can afford to practice it. It has been done on a limited scale to (a) check settling under surface improvements, (b) arrest and prevent "squeezes," and (c) extinguish or seal mine fires. In every instance an adequate supply of backfilling materials has been available, most of it from current operations. As essentially no economies in the cost of production accrue to the operator from backfilling, the practice has been followed only for the reasons mentioned.

Engineering Features of Hydraulic Backfilling Methods

It is not the intention to describe the engineering features of hydraulic backfilling methods in this report as the process of hydraulic backfilling is sufficiently well known to mining people. The engineering features of hydraulic backfilling in the Pennsylvania anthracite region, in metal mines, and in various European mining centers are described in technical literature (3, 4, 5, 7, 12, 15, 27, 28, 31, 34).

Hydraulic backfilling of chambers (rooms or breasts) should not be expected to support the roof permanently and prevent subsidence, when coal pillars either are present or are removed by subsequent mining. Culm as well as other backfilling materials, no matter how tightly placed initially, are compressible, the rate of compression increasing up to a certain limit beyond which culm or other backfilling materials cannot be compressed. According to Dierks (11), this limit is 18 percent of the original volume of culm as placed and is attained by a pressure of 3,000 pounds per square inch. Pressures of 2,000 pounds and 1,000 pounds per square inch compress culm 16 percent and 12 percent, respectively.

Extinguishing Mine Fires by Hydraulic Backfilling

Mine fires are a serious problem in the anthracite region and have cost mining companies millions of dollars and destroyed millions of tons of anthractic reserves.

Hydraulic backfilling has been and is now being used either to extinguish or to seal off mine fires (3, 15). Millions of dollars have been spent utilizing that method; however, it cannot be concluded that all mine fires can be thus extinguished, controlled, or sealed off. Experience has proved that unless the area surrounding the fire can be observed, air excluded from the fire, and the ground cooled, the chances of extinguishing a mine fire by hydraulic backfilling are remote if not entirely absent.

The number of fires that have been extinguished successfully or that have been brought under control justifies the method of hydraulic backfilling for these purposes under conditions favoring the use of the method.

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Several mine fires in the anthracite region have destroyed millions of tons of anthracite reserves and in all probability will destroy millions more. Aside from the loss of coal reserves and the constant threat to mines and communities in the vicinity of the fires, thousands of dollars are spent annually in combating them.

The Bear Valley mine fire, near Bear Valley colliery, Shamokin, was caused by a forest fire, which ignited the outcrop of the Mammoth vein in 1910. Over $400,000 has been spent in a vain effort to control and extinguish this fire by fighting it direct, by hydraulic backfilling, and by flooding.

In 1915, a fire was discovered underground at the Red Ash Coal Co. mine and resulted in loss of the mine. This fire has never been extinguished, and throughout the years all known methods of fire fighting, including hydraulic backfilling, have been employed in attempting to do so. To keep the fire from spreading towards active mines requires constant use of fire-fighting procedures. This work has cost 1-1/2 million dollars to date and a continuous annual expenditure of about $20,000, most of which is for hydraulic backfilling.

These fires can be extinguished by a combination of hydraulic backfilling and other methods, but it is beyond the financial ability of active mining companies to do the work. Developments in stripping operations have proved that where the ground can be cooled off and the fire isolated by hydraulic backfilling or flooding, there is hope that many fires can be extinguished and anthracite reserves saved. The Summit Hill fire existed for 83 years, and the coal reserves are now being recovered by stripping (21). Similar operations are underway in other mine-fire areas.

Pneumatic Backfilling

Water supply is one of the chief concerns in hydraulic backfilling. The cost of backfilling largely depends on the volume of solid materials handled and the quantity of water used.

When the pumping facilities of a mine are limited, owing to regular requirements, the cost of hydraulic backfilling is increased; in some instances the additional cost prevents the use of the backfilling method.

In some instances the water draining from backfilled mine workings flood gangways (roadways) or may even inundate whole sections of a mine. For this reason, an elaborate system of sumps must be maintained for the accumulation of the large quantities of water which hydraulic backfilling requires. Furthermore, if the bed dips steeply, hydraulic backfilling is a very hazardous undertaking. All this reacts unfavorably against this method except where conditions are relatively favorable.

To obviate the use of water as the carrying medium, air has been used instead, and pneumatic backfilling methods have been developed. The problems involved in this method have been solved gradually by coal-mining

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engineers in Europe, and at present the process is being used successfully in Germany and Great Britain.

The process of pneumatic backfilling in Germany has been described by Dierks (8), and at the Bullcroft main colliery, Carcroft, Doncaster, by Willett (41).

Need of Backfilling Anthracite-Mine Workings

Action to prevent cave-ins and subsidence should be planned to fit each specific place and condition. The people living in a locality affected by subsidence have the right to expect that something effective will be done to prevent serious accidents, but whether the work is done by the anthracite industry or by the State or Federal government, or by cooperation of some or all of them, is not the concern of these people.

To expect the anthracite industry to correct conditions conducive to subsidence that have been created by mining practices in what are now inaccessible mine workings or abandoned mines is expecting the impossible, chiefly because such a program, aside from not being feasible, is beyond the financial ability of the industry to perform. However, much can be done and should be done to control subsidence and to minimize its effects in present and future mining operations; logically, this should be done cooperatively by the industry and the State and Federal governments, inasmuch as all three agencies have a definite interest and obligation.

Five of the fifteen billion tons constituting the Pennsylvania anthracite reserves may be produced under existing mining conditions, provided markets for anthracite are available and the mine-water problem threatening the industry with premature extinction is solved (19). This estimate contemplates a loss, from various causes, of 9 to 10 billion tons of anthracite reserves. It is not unreasonable to assume that half of this estimated loss can be avoided if suitable remedial measures are placed in effect without undue delay. One of these is the backfilling of mine workings (where feasible) as future reserves are mined and also of open, unsupported, abandoned workings now in existence.

A total investment of 407 million dollars in anthractie lands, deposits, and other property useful in the production of anthracite was reported at the end of 1936 (6, 14). The value of anthracite lands and deposits is estimated at 250 million dollars and that of other property and equipment at only 157 million dollars.

For 1943, the value of Pennsylvania anthracite output at the mine was $206,816,018 for a total of 60,643,620 net tons. In other words, $206,816,018 of new values were created during 1943 by anthracite mining. Considering that 4-1/2 billion tons of anthracite having an estimated value of 22-1/2 billion dollars can be saved for the Nation's economy if a program of conserving anthracite reserves is effected, and that if nothing is done this value is lost forever, the need for conserving anthracite is evident. That the Federal Government should participate in an attempt to

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solve problems that threaten the premature extinction of the anthracite industry also should be apparent, especially when it appears almost certain that little or nothing will be done unless the Federal Government participates actively. The backfilling of anthracite-mine workings can contribute much towards removing that threat, provided action is not delayed unduly.

Anthracite Backfilling Problem

The improved surface overlying the Pennsylvania anthracite measures consists of 100 square miles of the total of 480 square miles of anthracite measures. Sixty percent of the improved-surface area is situated in the Northern Field, where hydraulic backfilling is applicable.

Surface of relatively small value, as compared with the underlying anthracite, does not usually justify backfilling to minimize subsidence; however, where the safety or the economy of the operation of the mine is involved, or where the recovery of more of the anthracite reserves is possible, some method of backfilling is justifiable.

Projects on backfilling in the anthracite region have been estimated to cost more than 70 million dollars; however, few engineering data are available and few projects have been developed for the anthracite region as a whole on the problem of backfilling as a means of preventing damage from subsidence or for the purpose of recovering anthracite reserves.

Data on the anthracite-backfilling problem reveal that it is the considered opinion of mining engineers concerned, who are familiar with the conditions, that in some instances backfilling can minimize damage caused by subsidence and effect a substantial saving of anthracite reserves that otherwise would be lost. The backfilling method, or methods, that could be used successfully can be determined or devised only by a sound engineering study of the anthracite backfilling problem and related problems (2, 3, 19, 38); however, any such study that does not result in a program that can be financed and completed within a reasonable period will serve no useful purpose.

CONCLUSIONS

1. The interest of the Federal Government in the anthracite-backfilling problem is based as much upon human values as it is upon the economics of the industry and of the various regions (cities and States) served by the industry.

2. The need to solve serious problems resulting from mining in the anthracite region is recognized, but the industry is utterly unable, financially, to deal with them effectively.

3. Single ownership could do much to prevent flooding and mine fires, to minimize serious mining subsidence, and to conserve anthracite reserves.

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4. The subject of subsidence is filled with uncertainties, contradictions, and difficulties of interpretation; suitable answers to individual problems are available, but no infallible formula to cover the entire industry is at hand.

5. A sharp distinction has to be drawn between subsidence and damage resulting from subsidence.

6. The risk of inundation of mines in sections of the anthracite region is increased by subsidence of strata overlying mine workings filled with loosely consolidated water-bearing materials.

7. The damage and the harmful consequences of subsidence can be prevented or lessened by tightly filling the mine workings when the coal is extracted and the workings are open for inspection.

8. Virgin anthracite that can be mined by underground methods is now largely restricted to beds underlying improved surface areas.

9. A real problem must be solved to permit robbing operations (or complete removal of pillars) under improved surface areas if reserves are to be recovered without incurring danger to life and property thereon.

10. In spite of all the studies that have been made and the reports that have been written, the subsidence problem remains acute today largely because suitable action has not been taken in places where it exists.

11. It is the considered opinion of well-informed mining men that serious damage resulting from subsidence can be prevented, and anthracite reserves can be recovered only by some system of backfilling.

12. Planning of either a short- or long-term anthracite program is justifiable and desirable.

13. Comprehensive study of the anthracite backfilling and related problems is a sound investment for the Federal Government, the State, and the mining companies. All three have a responsibility, and no single agency can handle the problem alone.

14. As much of the damage affecting anthracite reserves has already been done, measures should be taken to avoid further losses. The need for conservation of anthracite, which is an important national asset, indicates that the Federal Government should assume leadership in planning to solve this problem and should also aid in the actual work of construction.

15. A comprehensive engineering study of the anthracite backfilling problem by the Federal Government, costing $250,000, is recommended, the work to be done in cooperation with the Commonwealth of Pennsylvania and the anthracite industry, provided that such a study leads to action.

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